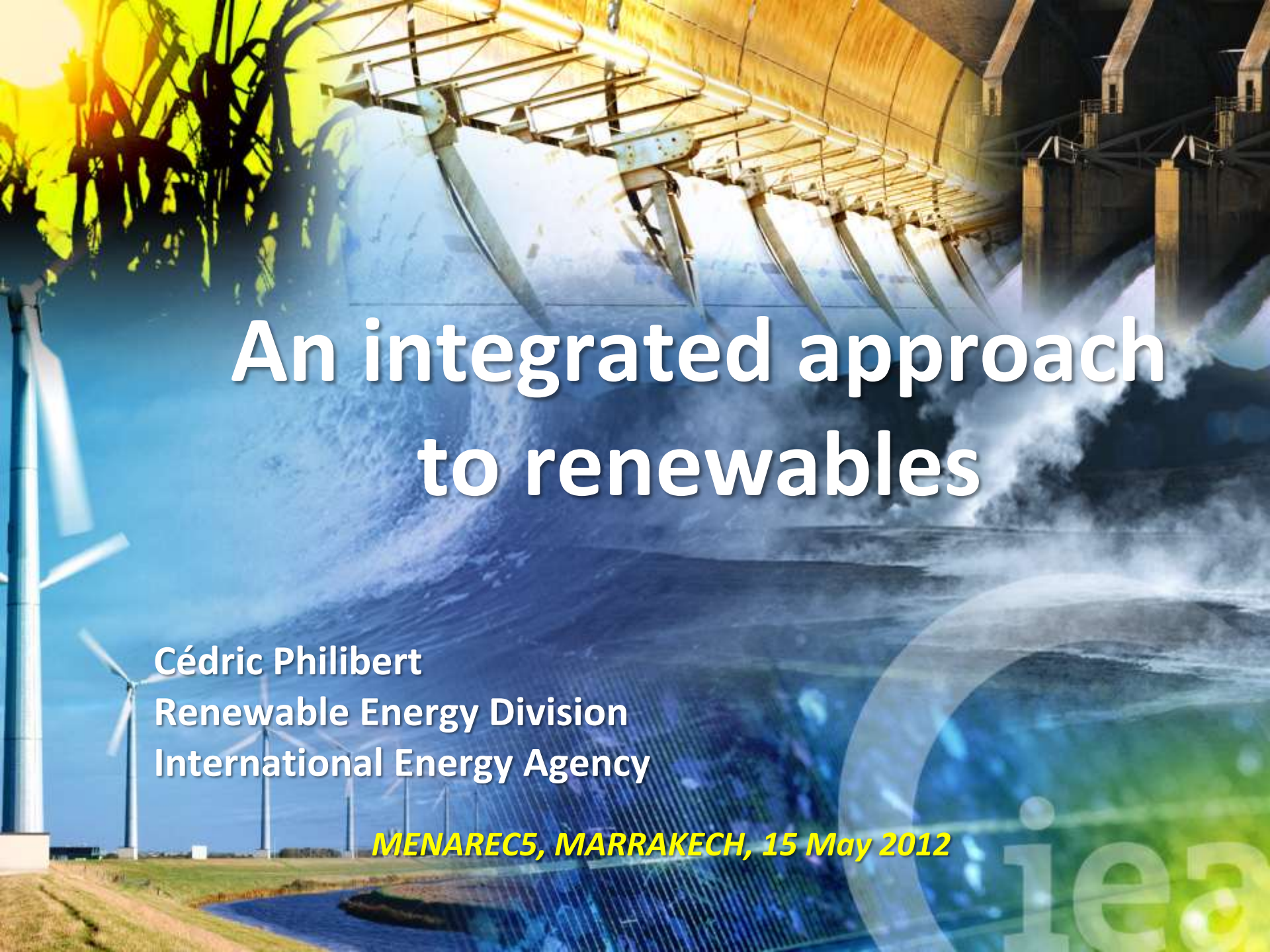


An integrated approach to renewables

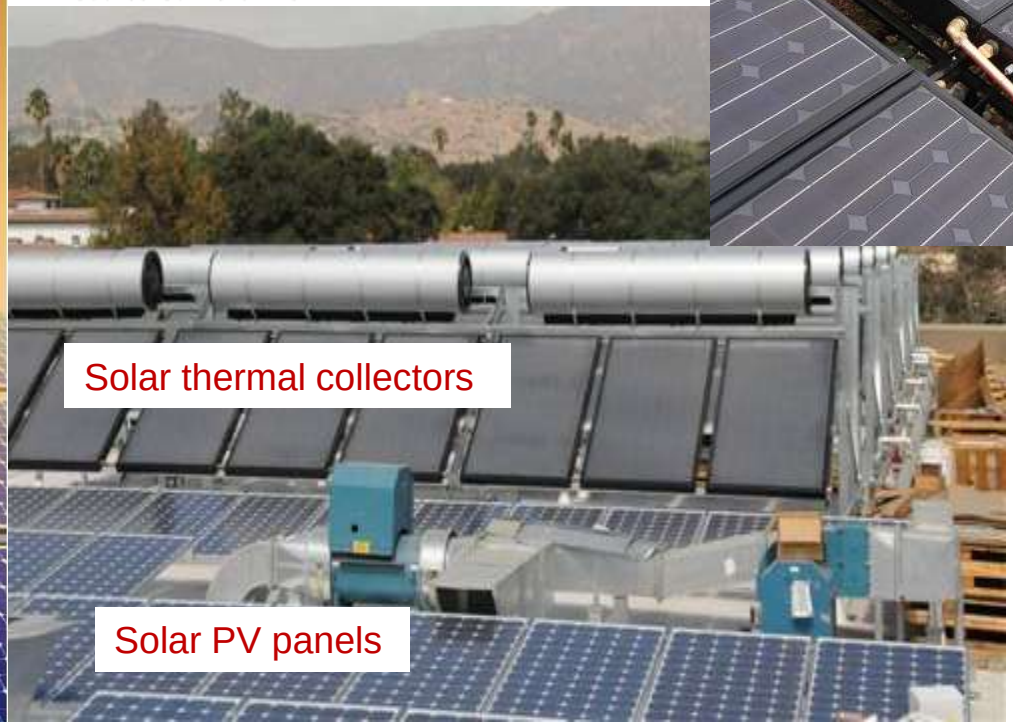
Cédric Philibert
Renewable Energy Division
International Energy Agency

MENAREC5, MARRAKECH, 15 May 2012

In search of synergies…

- Between various solar technologies
- With other RE/EE technologies

Source: SunEarth Inc.



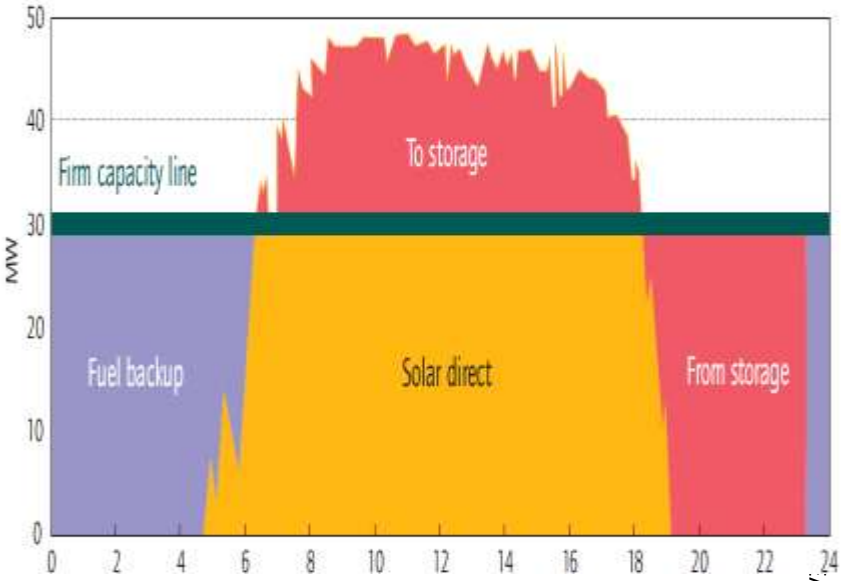
Source: Solimpeks Solar Energy

- Driven by analyses of the demand for various uses

Markets: Electricity

- PV takes **all** light
- PV almost **everywhere**
- Mostly at **end-users'**
- **Variable**
- Peak & mid-peak
- Grid parity **by 2020**
- **Smart grids**

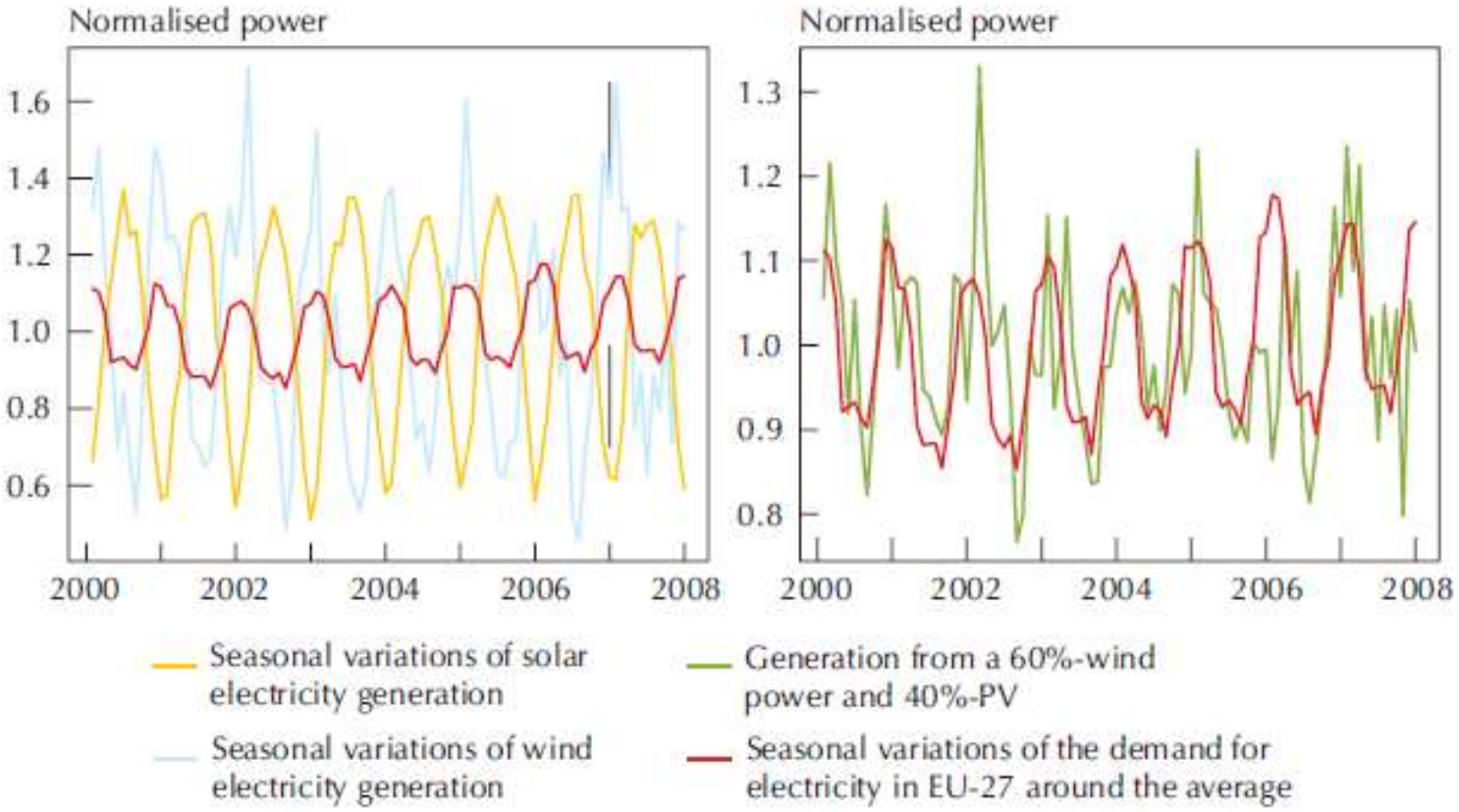
- CSP takes **direct** light
- CSP **semi-arid** countries
- Mostly for **utilities**
- **Firm**, dispatchable } backup
- Peak to **base-load** } storage
- Competitive peak power **by 2020**
- **HVDC lines** for transport



Firm & flexible CSP capacities can help integrate more PV

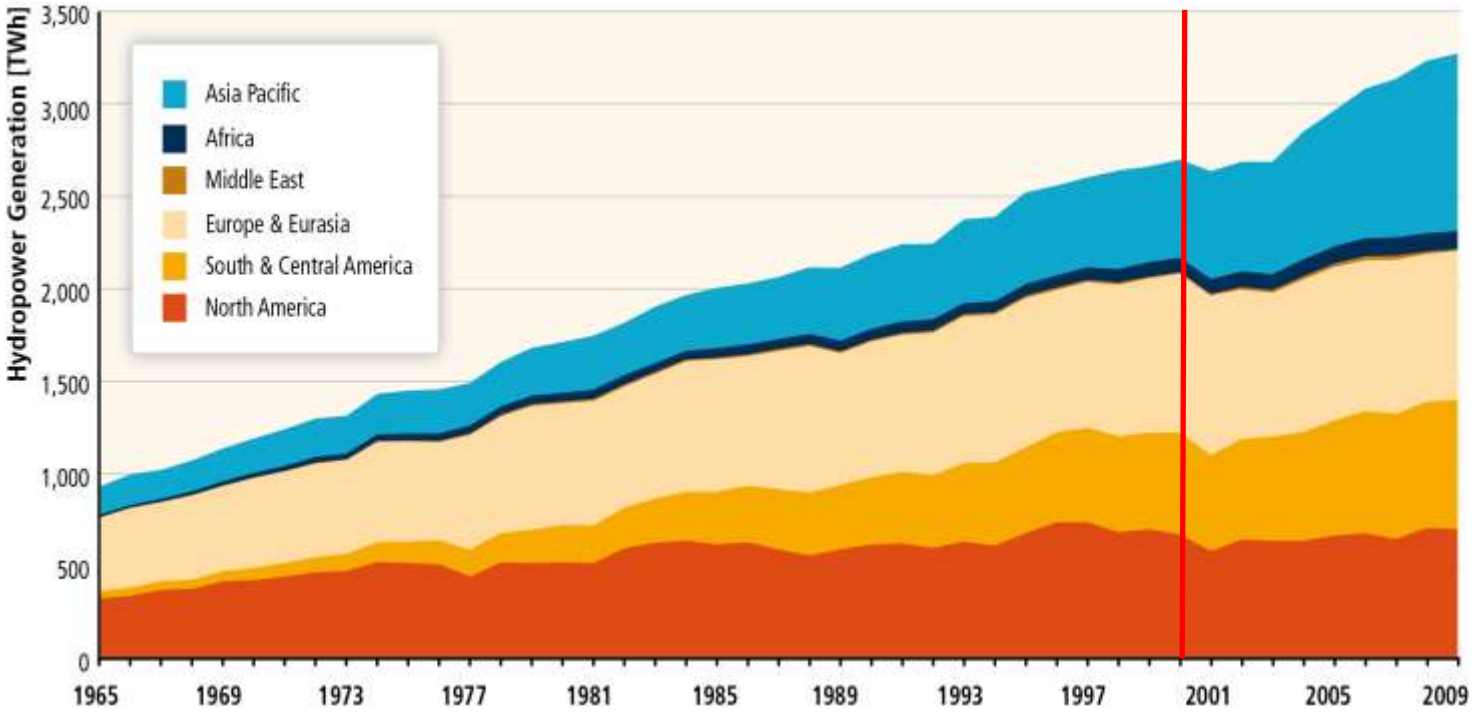
A, 2011

Storage needs for large-scale variable RE



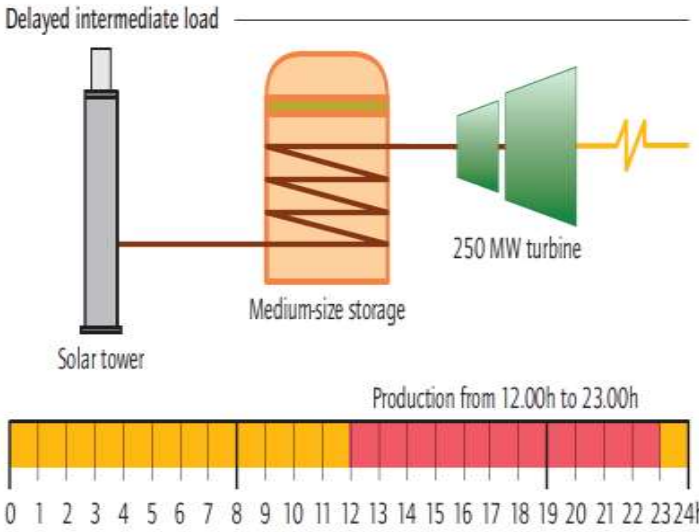
- **Hourly/daily storage for PV and wind**
- **For rare long periods without wind or sun, better use balancing plants**
- **Inter-seasonal storage needed in some cases**

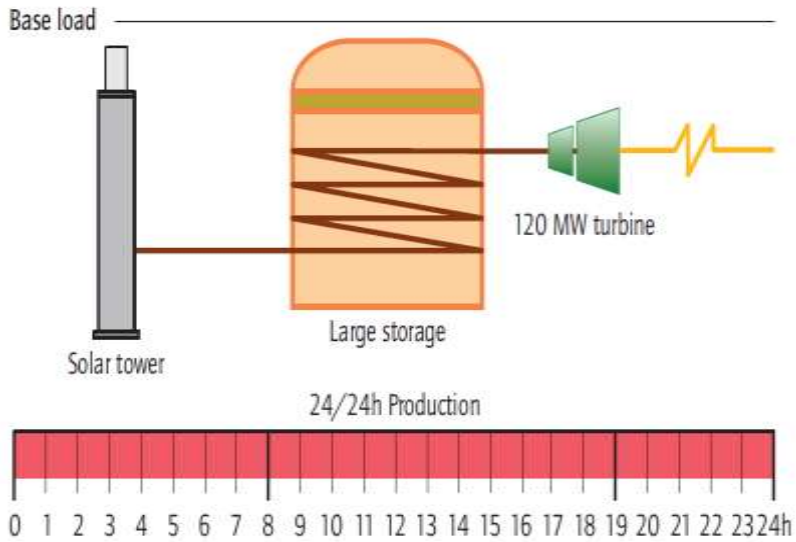
Hydro & pump-hydro: enablers of vRE growth

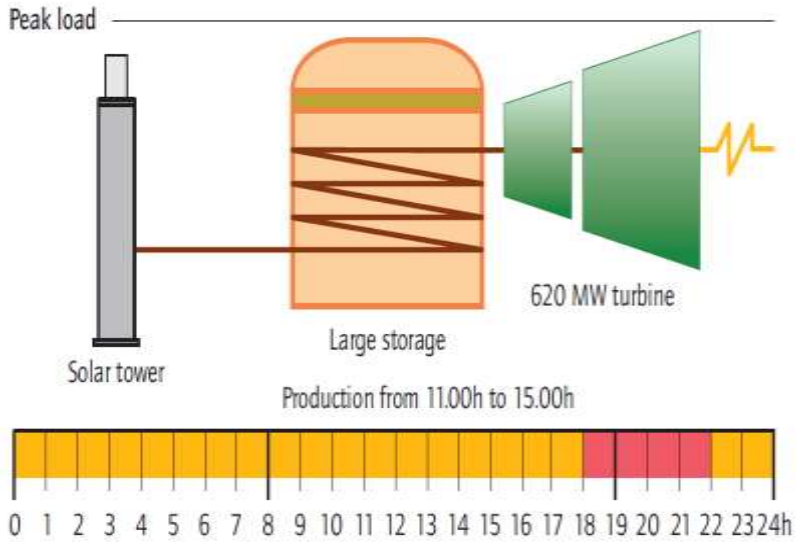


- Hydropower generation continues growing as fast as all non-hydro renewables together since 2000
- Global pumped-hydro capacities: 98 GW by 2005, 140 GW today, up to 200 GW by 2015 or soon thereafter

Possible roles of storage in CSP plants







- **Thermal storage can be used to shift production, to extend it to base load or to concentrate it to super peak load**

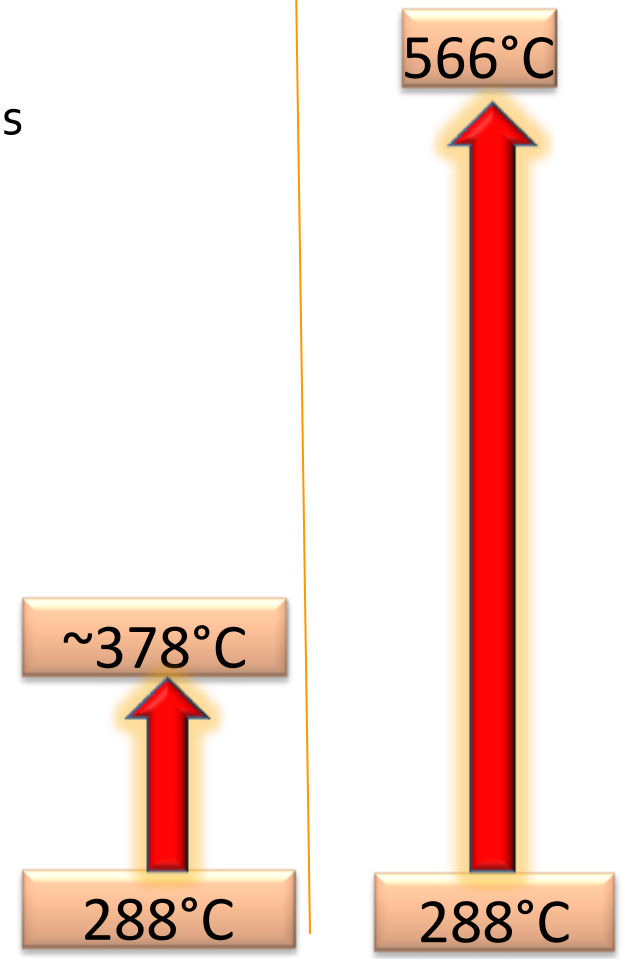
Temperatures and storage costs

Stored Heat =∑ mCp ΔT

Stored Heat is Proportional to *ΔT*

Large / Smaller ΔT ≈ 278°C/90°C

Low Temperature Storage Requires ≈ 3X mass



Low Temperature Storage ~ 3X Cost per MWt

Co-generation from CSP: an example from Morocco Oriental?

- Electricity demand is maximum and summer; output from CSP plants maximum in Spring
- Except for specific circumstances (large hydro, possibly with pump-back scheme), storage over several months way too costly
- However… demand of high-temperature process heat for sugar refineries is maximum in May, June and July…
- Excess or all solar steam could be used for sugar in three months, and electricity generated in the rest of the year…

CSP and desalination: no big gain

Solar Energy Perspectives

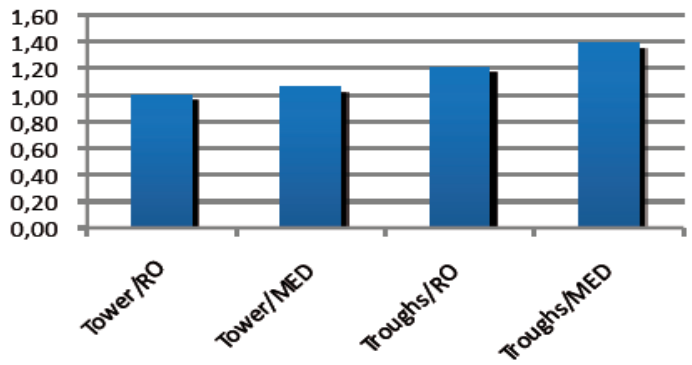
RENEWABLES ENERGY TECHNOLOGIES

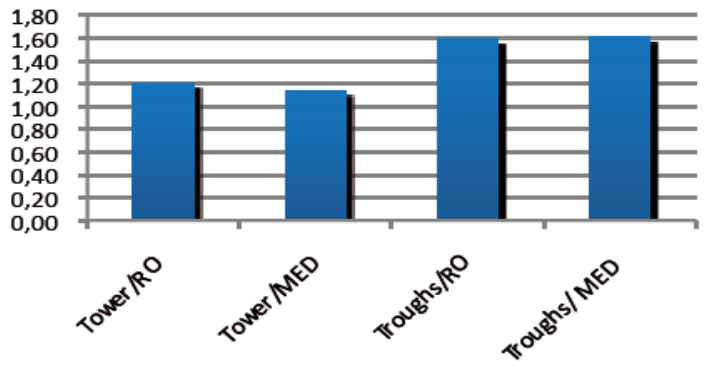
LOW SALINITY

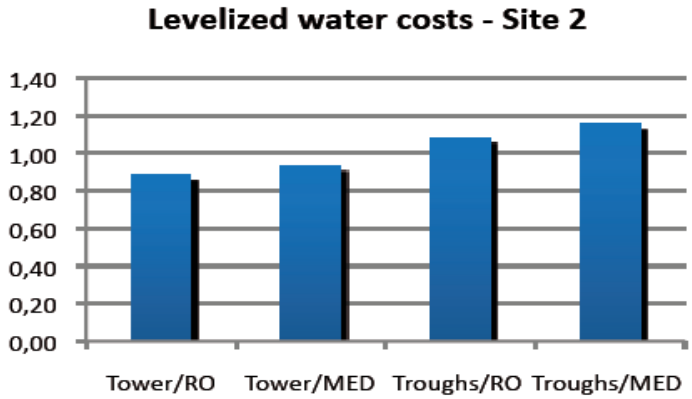
HIGH SALINITY

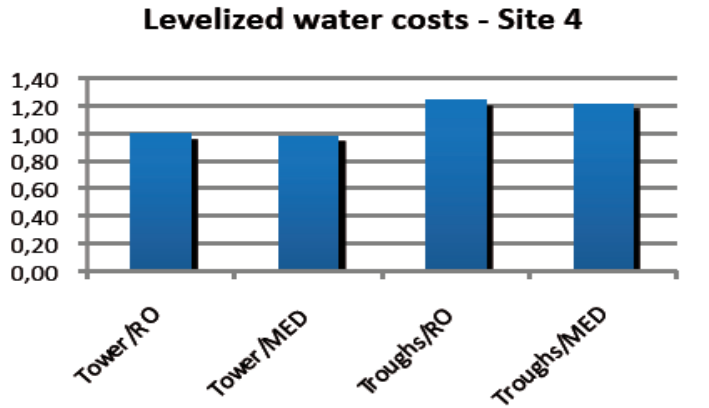
LOW DNI

HIGH DNI





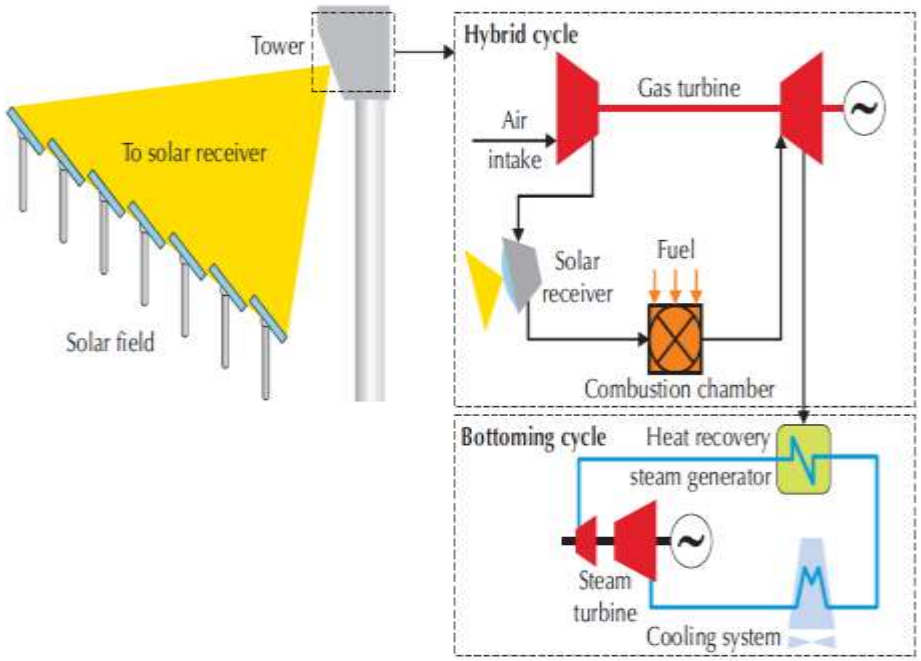




Back-up/hybridisation

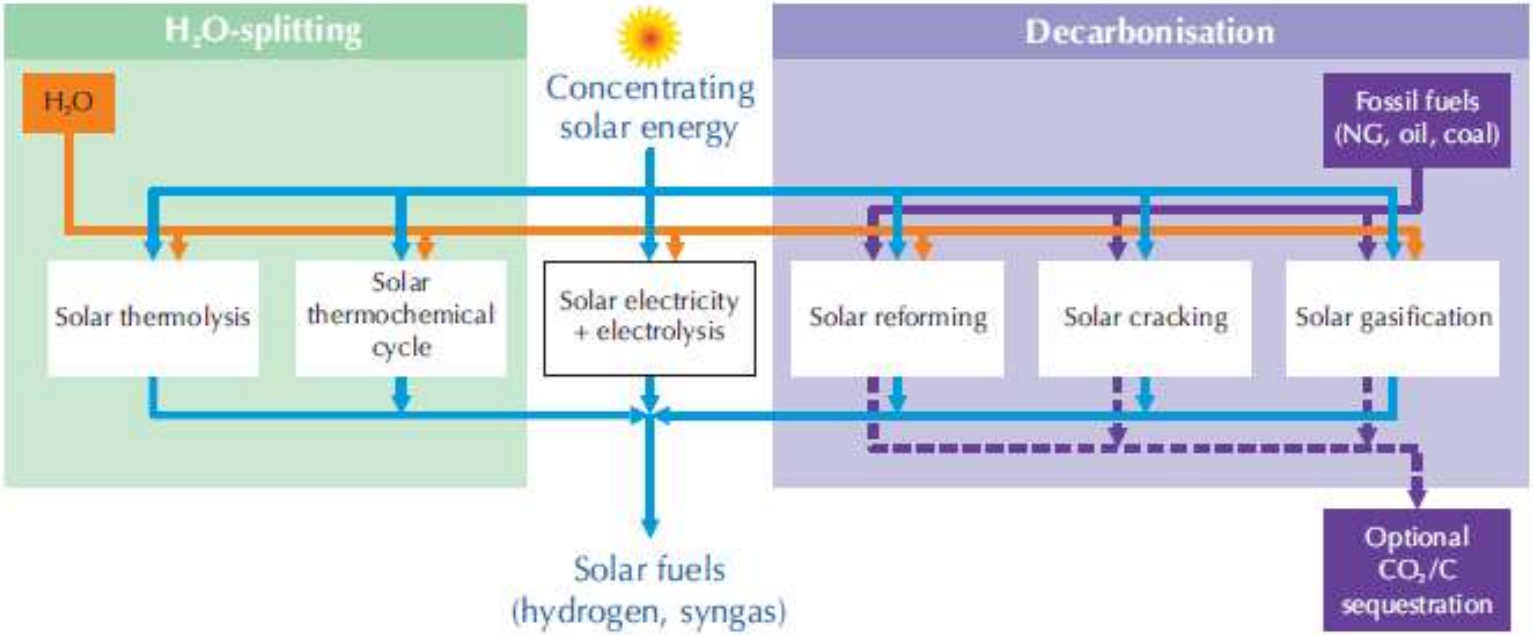
- Firming capacities
- Increase the solar share in the mix
- Walk the learning curve
- Currently in use:
  - Back-up or routine fuel use in PT plants; efficient?
  - Fresnel pre-heating feedwater in coal plants
  - Steam augmentation in bottoming cycles (ISCC)
- Options to be developped
  - Main steam augmentation in efficient coal plants
  - Hybrid solar-gas with combined cycle

Source: PEGASE/CNRS.



Solar fuels

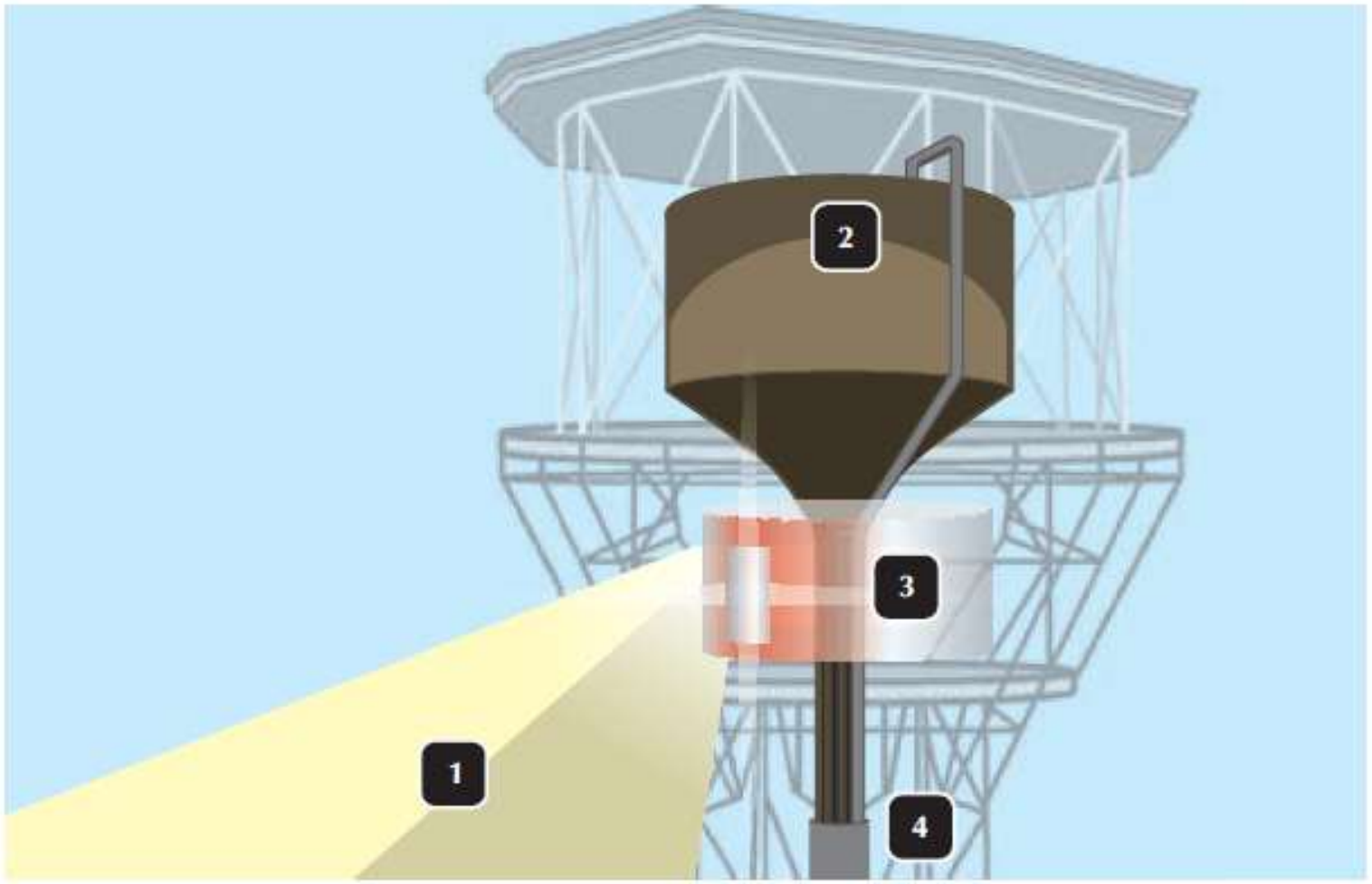
- From hydrocarbon (incl. biomass) or water
- Cheaper with high-temp. heat than electricity?



Source: PSI/ETH-Zürich.

- H_2 easier to store & use in blend w. natural gas
- Or solar heat reducing metal oxydes, then reacted with water generating H_2 on demand…

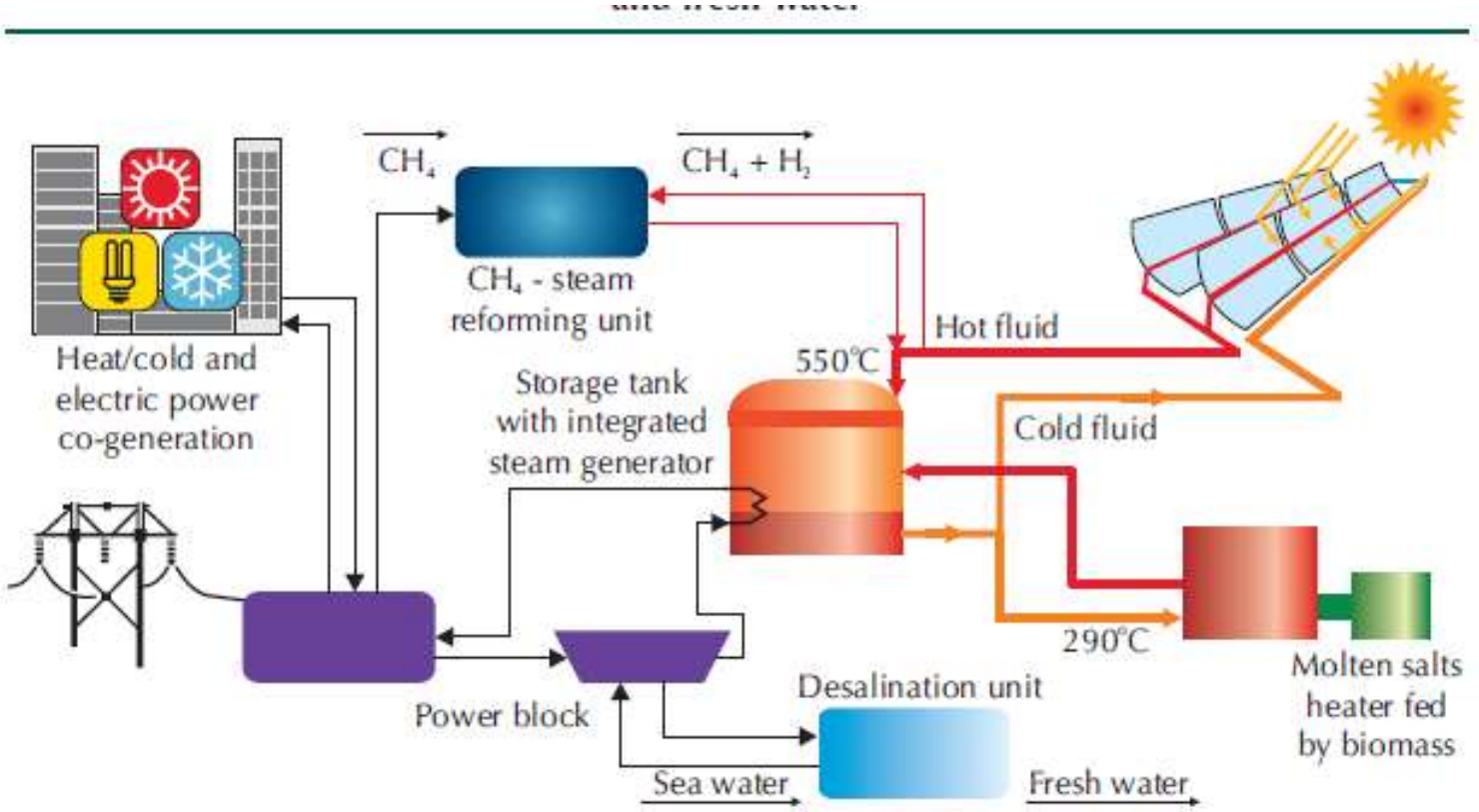
Solar-enhanced biofuels



Notes: 1. Concentrated solar power from heliostats on the ground is directed into the thermochemical reactor on top of a tower. 2. Finely ground biomass is delivered by pneumatic tube into a feeder unit above the reactor. 3. Feedstock is dropped through the reactor's solar furnace, where temperatures of 1300°C gasify the material. 4. Syngas is collected and delivered to the adjacent biorefinery to create green gasoline or diesel fuels.

Source: Sundrop Fuels, Inc.

CSP backed by biomass to produce power, heat or cold, hydrogen & water



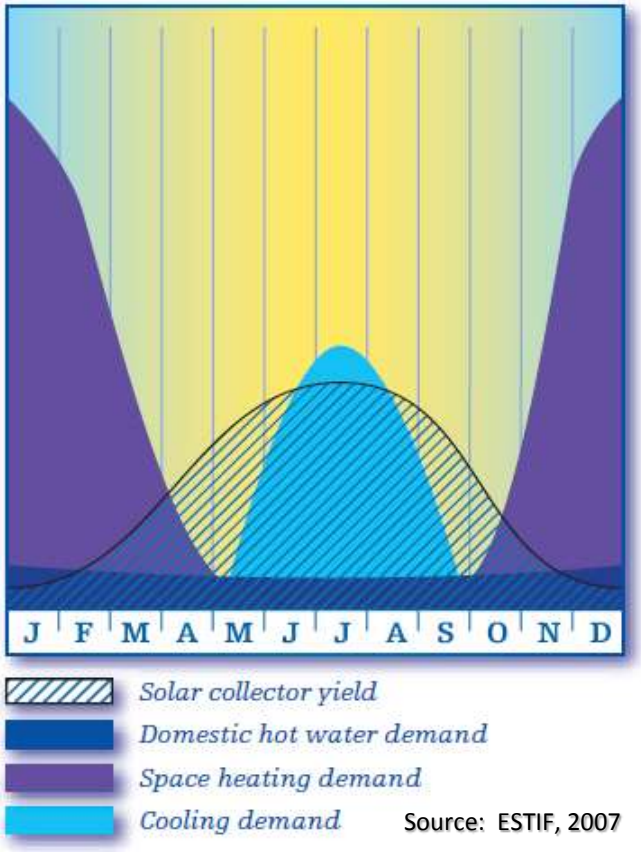
Source: ENEA-UTRINN-STD.

Focus: cooling

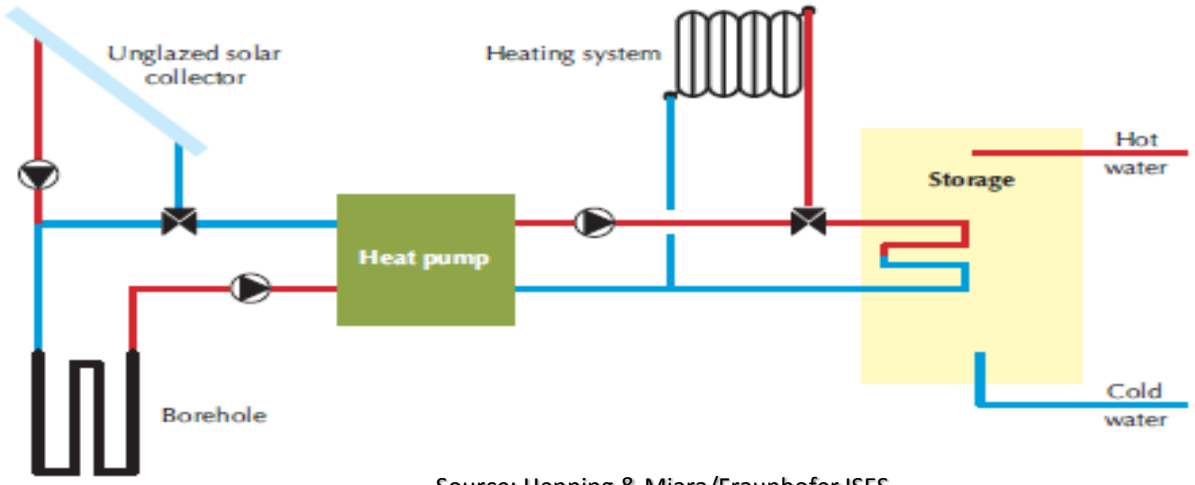
- Resource and demand match well
- Thermally-driven cooling?
- Cooling is ultimately work, not “heat”…
- Some large installations, but costs are often too high compared with “conventional” cooling devices run by (solar) electricity (centralised or decentralised)
- Air-conditioning daytime peak loads help make PV competitive
- Reversible ground-source heat pumps to respond to both cooling and heating demand with renewable electricity?

Solar space heating

- **Storage is key**
  - **Compact thermo-chemical?**
  - **Large-scale heat storage**
  - **Ground-source heat pumps = effective low-temp storage**
  - **Combining renewable electricity and ambient heat**



Source: ESTIF, 2007

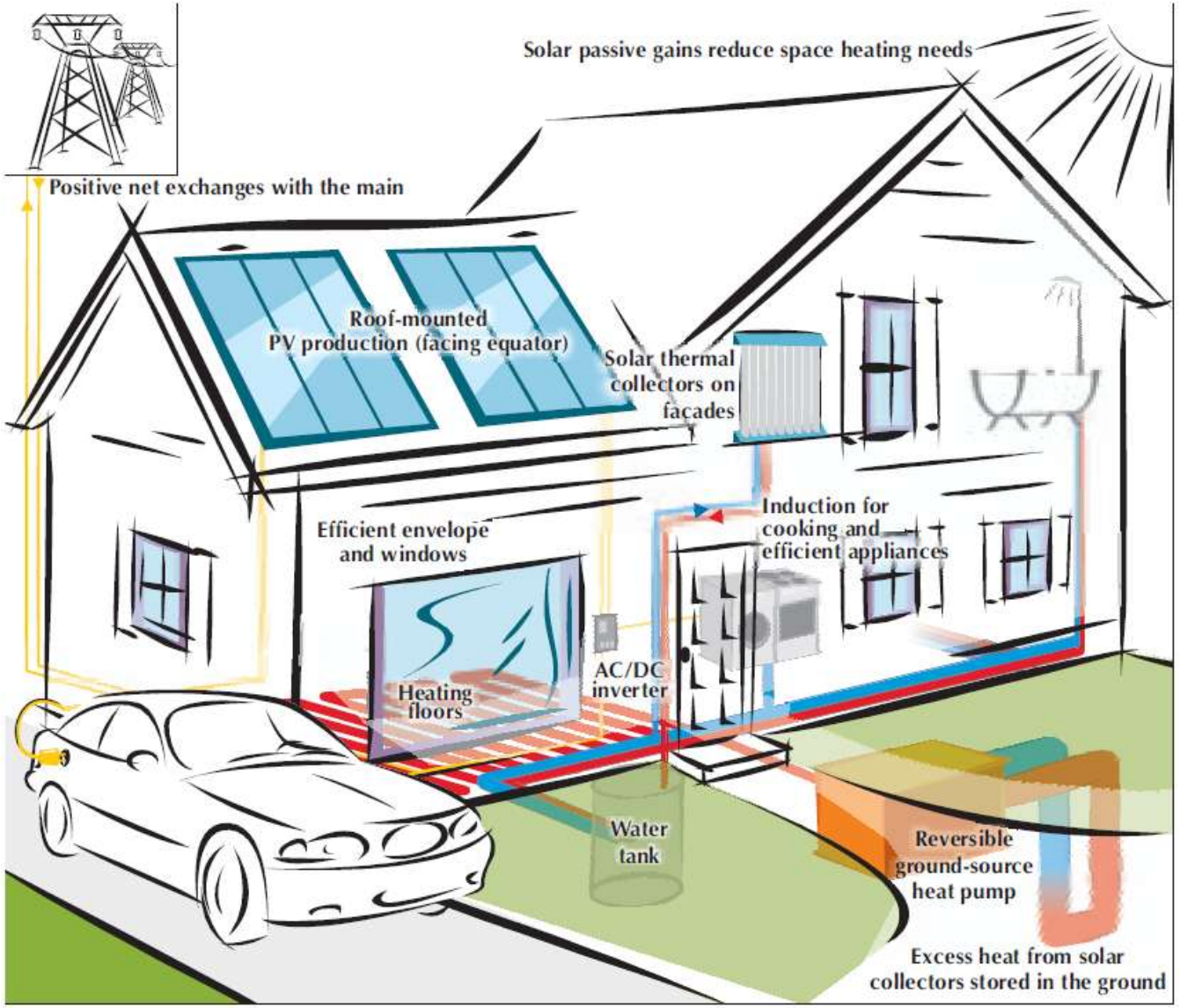


Source: Henning & Miara/Fraunhofer ISES

RENEWABLES ENERGY TECHNOLOGIES

Solar Energy Perspectives

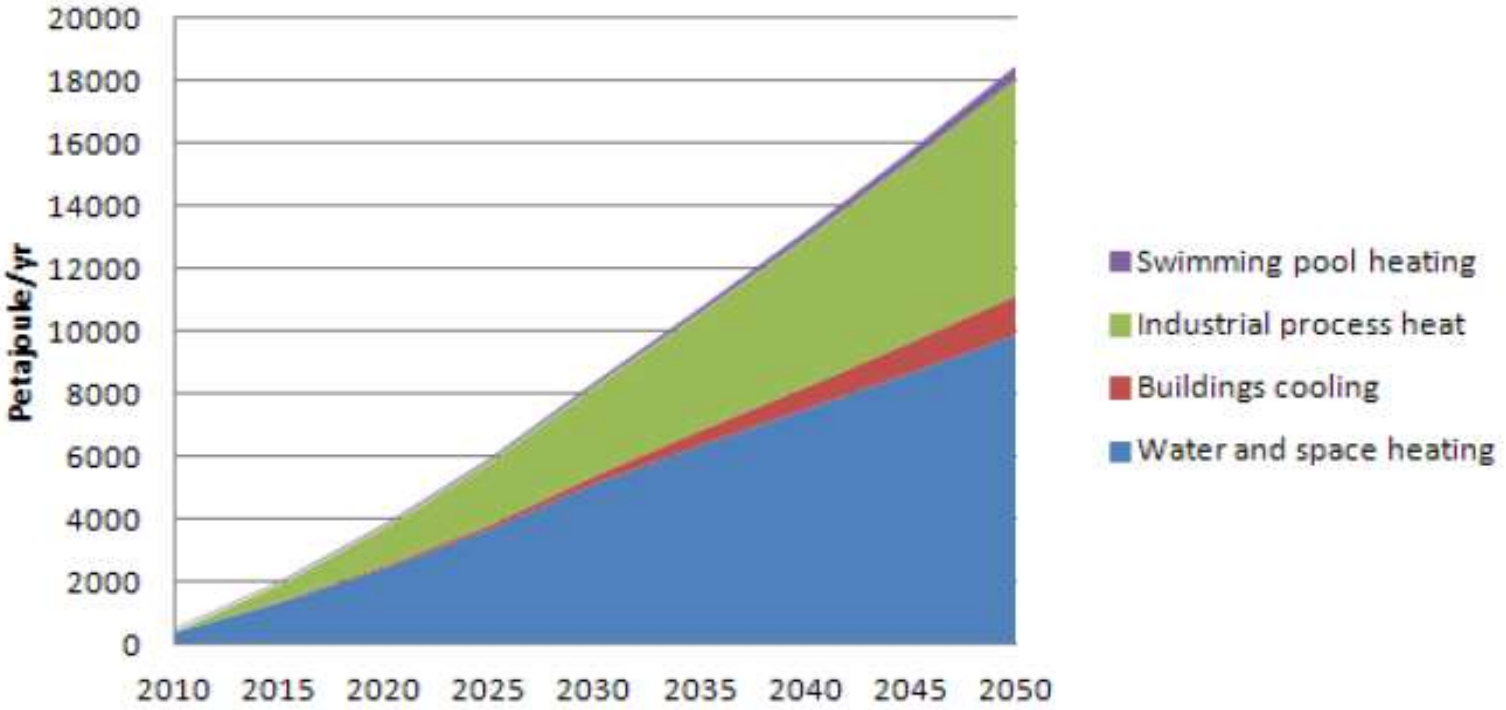
Buildings



An integrated approach increases efficiency and reduces total costs

Solar Energy Perspectives

Solar Heating and Cooling roadmap

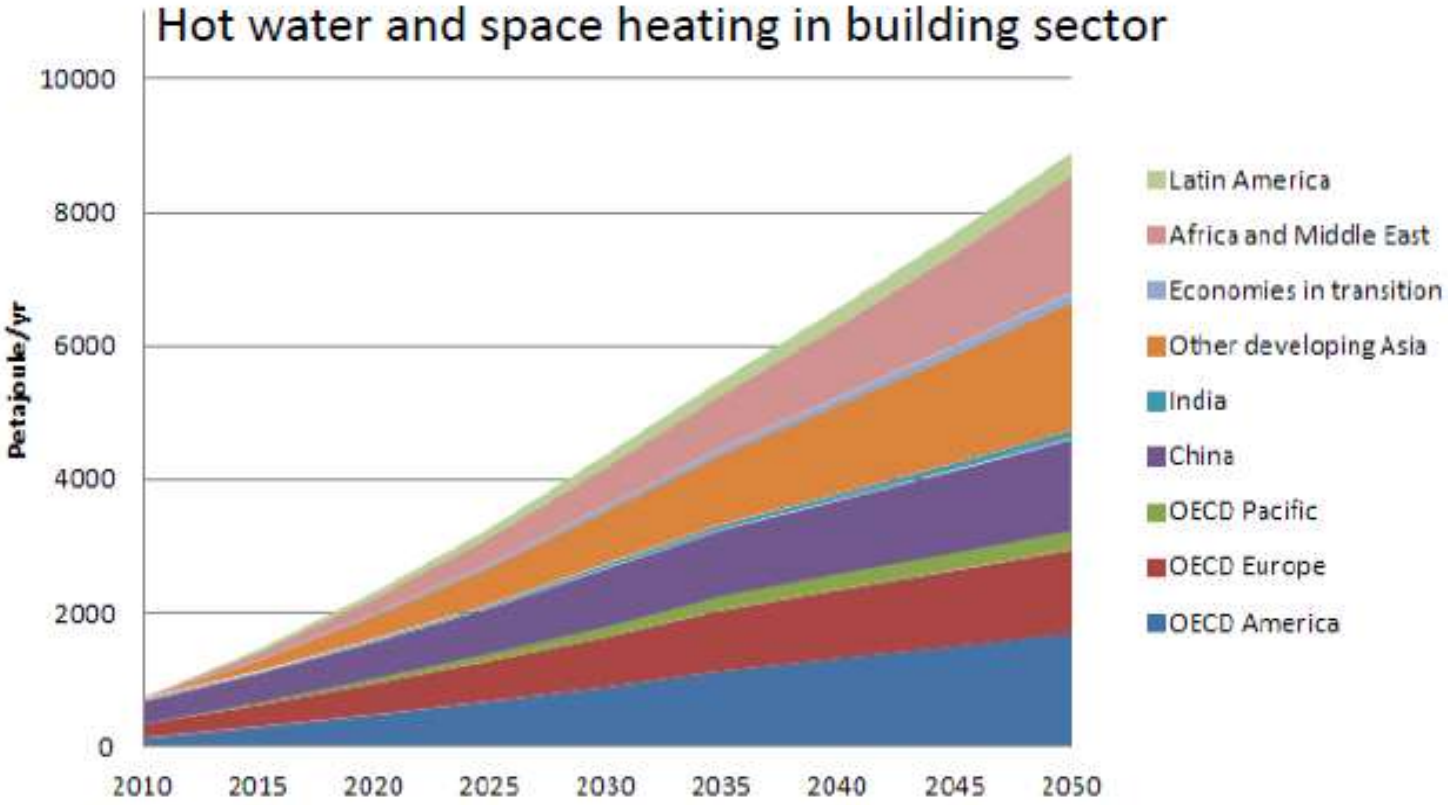


- 18 EJ annual solar heat production by 2050, some 10% of final energy for heat by that time
- 1.5 EJ annual solar heat for cooling by 2050

Solar Energy Perspectives

RENEWABLES ENERGY TECHNOLOGIES

Solar Heating & Cooling roadmap



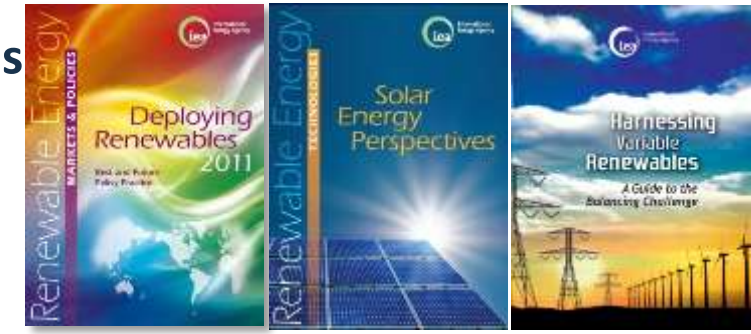
- **Solar heat can contribute to 8.9 EJ/y domestic hot water and space heating in buildings by 2050**
- **Large potential of solar-supported district heating**

Solar Energy Perspectives

RENEWABLES ENERGY TECHNOLOGIES

Building on our work...

- **Books**
  - Harnessing Variable Renewables
  - Solar Energy Perspectives
  - Deploying Renewables



- **Technology Roadmaps**
  - Wind Power
  - Concentrating solar power
  - Solar PV
  - Biofuels for Transport
  - Geothermal Energy
  - Forthcoming: Bio-energy for heat and power, solar heating and cooling, hydropower

- **Information Papers**
  - Renewable heat
  - Cogeneration and Renewables
  - Interactions of Policies for Renewable Energy and Climate